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Abstract

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STUDY OF THE VELOCITIES OF LONGITUDINAL WAVES IN ROCK SAMPLES AT PRESSURES UP TO 20,000 kg/cm^2

(Presented by Academician P. A. Rebinder, 30 IV 1964)

In connection with the study of the structure of the Earth' s crust and upper mantle by seismic methods, investigations of the velocities of elastic waves in rock samples at high pressures are necessary. Measurements of the velocities of longitudinal and transverse waves have been carried out for many igneous and metamorphic rocks at pressures up to 4000 kg/cm^2 ([1,2]). For a number of rocks the velocities of longitudinal waves have been determined at pressures up to 8000-10,000 kg/cm^2 ([3,4,5]). Such pressures correspond to depths of 30-35 km in the Earth' s interior. In the present work, investigations have been carried out of the velocities of longitudinal waves in rock samples at pressures twice exceeding the limit reached up to now in similar experiments. The high-pressure apparatus used is distinguished by the fact that, as the pressure-transmitting medium, instead of a gas or liquid, a plastic solid with a low coefficient of internal friction (lead) was used, analogously to the study of the compressibility of solids at high pressures ([5,6]).

The apparatus (Fig. 1) is simple in design: it consists of a high-pressure chamber 4, two pistons 3, two conical punches 2, and two supporting rings 6. All parts are made of alloy steel and heat-treated. In the end parts of the conical punches, two piezoelectric transducers 1 are mounted in the opening of the supporting ring, one of which serves as the source of ultrasound and the other as the receiver. The design of the high-pressure apparatus makes it possible to measure velocities of longitudinal waves lower than the velocity in steel. The rock sample 5 has the form of a cylinder 18 mm in diameter and 20 mm high; the diameter of the chamber channel is 20 mm. Before the experiment, the rock sample was mounted in a lead jacket of the corresponding size. In order to prevent lead from flowing into the gap between the pistons and the chamber walls, locking steel rings were used. During the experiment, the displacement of the pistons was measured with high accuracy by means of two dial indicators mounted on a special crosshead. Pressure in the chamber up to 20,000 kg/cm^2 was produced by means of a laboratory hydraulic 100-ton press.

Fig. 1. Diagram of the high-pressure apparatus

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As in the case of other apparatuses ([5],[6]) using lead to transmit pressure, the question arises as to how close the acting pressure is to hydrostatic. Measurements of rock samples before and after the experiment showed that no noticeable change in their dimensions occurs. Petrographic study of thin sections of samples subjected to pressure did not reveal any significant manifestations of deformation. Measurements of the velocities of elastic

of waves in the specimens before and after the experiment showed identical values. Hence it may be concluded that the pressures created in the chamber are sufficiently close to hydrostatic. It should be noted that a characteristic feature of this apparatus is the comparatively large diameter of the high-pressure chamber channel.

Table 1

Rock	Volumetric weight	Mineral composition, %	Structure, texture
Granite 732	2.58	Quartz 28, potassic feldspar 68, biotite 8, secondary minerals 6	Average grain size 0.6–0.9 mm; structure uniformly granular; texture granitic
Granite-gneiss 740	2.68	Quartz 21, potassic feldspar 65, biotite 12, secondary minerals 2	Average grain size 0.5–0.8 mm; structure uniformly granular; texture weakly gneissose
Biotite-quartz-plagioclase gneiss 460	2.84	Plagioclase 75, biotite 16, quartz 9	Average grain size 0.6–0.8 mm; structure uniformly granular; texture weakly gneissose
Onega diabase 3	3.08	Plagioclase 50, monoclinic pyroxene 25, hornblende 10, ore mineral 15	Average grain size 0.5–1 mm; structure ophitic

Rock	Volumetric weight	Mineral composition, %	Structure, texture
Altered gabbro-norite 466	2.95	Rhombic pyroxene 28, plagioclase 37, quartz 10, biotite 16, hornblende 5, chlorite and ore mineral 4	Average grain size 1–3 mm; primary structure not preserved; texture massive
Peridotite 455	3.28	Olivine 56, rhombic pyroxene 25, magnetite 5, serpentine 14	Average grain size 3–4 mm; structure panidiomorphic, locally poikilitic; olivine grains surrounded by rims of serpentine
Peridotite 609	3.34	Olivine 60, rhombic pyroxene 20, plagioclase 15, biotite (secondary) 2, magnetite 3	Average grain size 2–3 mm; structure panidiomorphic, locally poikilitic, homogeneous, uniformly granular

The velocities of elastic waves were determined by means of a pulsed ultrasonic apparatus, which had previously been used in studying the absorption and velocities of elastic waves in rock specimens under high confining pressures. Piezoelectric ceramic transducers of the piston type, with a natural oscillation frequency of 1 Mc/s, were used to excite elastic vibrations. Velocity values were calculated from the travel time of elastic vibrations in the rock specimens, which was determined from the difference between the travel times of elastic waves in the system with the specimen and without the specimen. This method eliminates various time corrections in the electronic apparatus. The travel time of the elastic waves was read with an accuracy of 0.02–0.05 μsec, and the error in determining the velocity did not exceed 2–3%.

By the method described, 7 specimens of igneous and metamorphic rocks from the Kola Peninsula, mostly taken in the Monchegorsk area, were studied. A brief petrographic characterization of the rocks is given in Table 1; the velocity values are seen from the graphs in Fig. 2.

Fig. 2. Change in longitudinal-wave velocities as a function of pressure in rock samples (the numbers next to the curves correspond to the rock numbers in Table 1)

Figure 2: Fig. 2. Change in longitudinal-wave velocities as a function of pressure in rock samples (the numbers next to the curves correspond to the rock numbers in Table 1)

It is evident from Fig. 2 that the velocity of longitudinal waves for all the rocks studied increases continuously with pressure. The most significant increase in velocities occurs in the initial region, in the pressure interval 1-2000 kg/cm^2. In the pressure interval 2000–6000 kg/cm^2 a slower increase in velocity is observed; with further increase in pressure, for all rocks except granites, a new, rather considerable increase in velocities is noted. In granite and granite-gneiss, in the pressure interval 2000–20 000 kg/cm^2, a very weak increase in velocity is observed. In contrast to granites, for diabase and peridotites in this pressure interval a considerable increase is observed.

velocity. It is characteristic that two peridotites (455 and 609), having approximately the same mineral composition, possess different velocities and show a different course of the curves. This, apparently, is explained by the different freshness of the rocks, which is reflected also in their density and mineral composition (see Table 1). The presence in sample 455 of secondary serpentine

Fig. 2. Change in longitudinal-wave velocities as a function of pressure in rock samples (the numbers next to the curves correspond to the rock numbers in Table 1)

in an amount of 14% probably leads to a considerable decrease in velocity. As is known ([3]), the velocity of longitudinal waves in serpentine is 6000 m/sec, and in olivine 8500 m/sec.

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