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Shock Compression of Shoal Granite

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Experiments utilizing explosives with and without flyer plates have been used to determine the shock compression properties of shoal granite. High-speed framing camera records were used to determine the free surface angles which occur in wedge-cut samples upon the emergence of the resulting shock waves. The shock equations are given for the oblique geometry. Previously observed yield point data are used to obtain the Hugoniot of shoal granite in the range between 0 and 400 kbars.

I. INTRODUCTION

A number of reports and publications have given high-pressure data for granite.[1–4] Attempts to plot these data on a single curve sometimes show considerable scatter.[2,5] Such scatter is no doubt due in part to experimental errors and sample to sample variation but may also be partially attributable to differences in the materials studied. Materials with a fairly wide variation in the proportion of mineral abundancies fall under the general classification of granite.

In this paper the results of high-pressure shock compression experiments on shoal granite are given.[6] The mineral content of this material was reported in a previous paper[7] where the results of experiments for shock pressures up to about 40 kbars were given. In the earlier work a shock tube method was used; here high explosives were used to obtain pressures up to about 400 kbars. The object of this work is to furnish shock data for one particular type of granite throughout the complete range up to 400 kbars.

II. EXPERIMENTAL METHOD

Two different configurations were used to generate a shock wave in a wedge-cut sample of granite. In the first, as shown schematically in Fig. 1, an explosive train consisting of a detonator, plane wave generator, and pad of high explosive were used to impact a flyer plate upon the sample. In the second, the explosive train was placed in direct contact with the sample. In both configurations, a shock wave was generated in the sample which caused free surface motion of the back face of the sample. A framing record of the slit and fiducial markings between the sample and knife edge were recorded on a Beckman Whitley model 189 framing camera. The slit area was back lighted by an argon light bomb detonated prior to the free surface motion. The

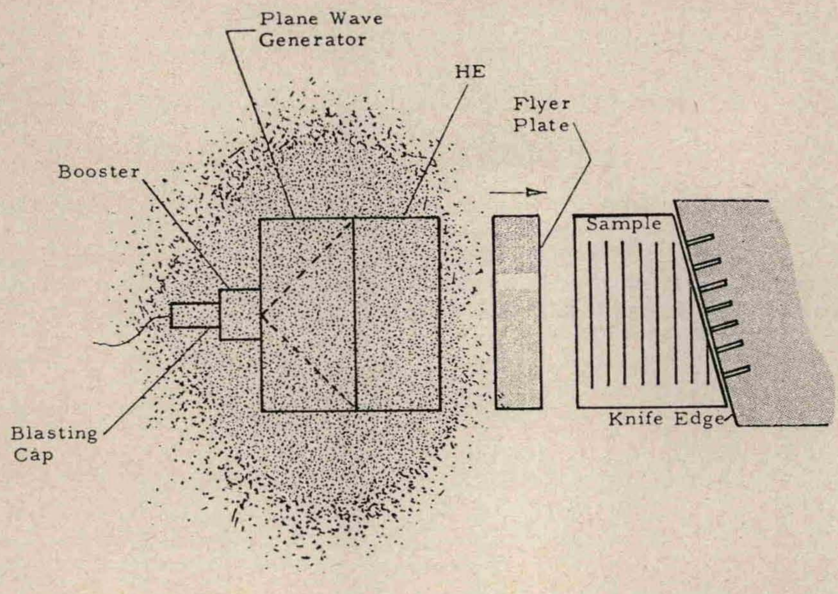

FIG. 1. Configuration for explosively driven flyer plate experiments on wedge-cut samples.

timing sequence was determined by the position of the rotating mirror in the framing camera. Thus, at a predetermined rotor position after detonation of the explosive train, the argon flash was detonated. A gating scheme was used to ensure that the triggering signal generated during each revolution of the camera rotor did not ignite the argon flash until after the explosive train was detonated. The explosive train was detonated when the rotating mirror reached the desired rotational velocity.

A record of the free surface configuration is shown in Fig. 2. From a series of such consecutive records, the shock wave and free surface velocities were calculated.

III. SHOCK WAVE EQUATIONS

In a number of investigations the shock equations have been used. These equations relate the one-dimensional strain and the diagonal stress tensor component in the shock propagation direction to the measurable variables, the shock and material velocities. For a single shock wave propagating into initially unstressed material the stress and strain are

$$\sigma=\rho_0 U_s U_p \tag{1}$$

and

$$\epsilon=\Delta V/V_0=U_p/U_s, \tag{2}$$

where U_s and U_p are the shock wave and material velocities and ρ_0 and V_0 are the initial density and volume, respectively. The stress σ differs from the hydrostatic stress when the shear modulus has a finite value. For very high stresses the shear modulus vanishes and the diagonal stresses are equal to the pressure. In most of the experiments discussed here the stress level is not high enough to neglect the shear forces so that the value of σ found from Eq. (1) cannot be thought of as the hydrostatic pressure, and shear waves can be expected.

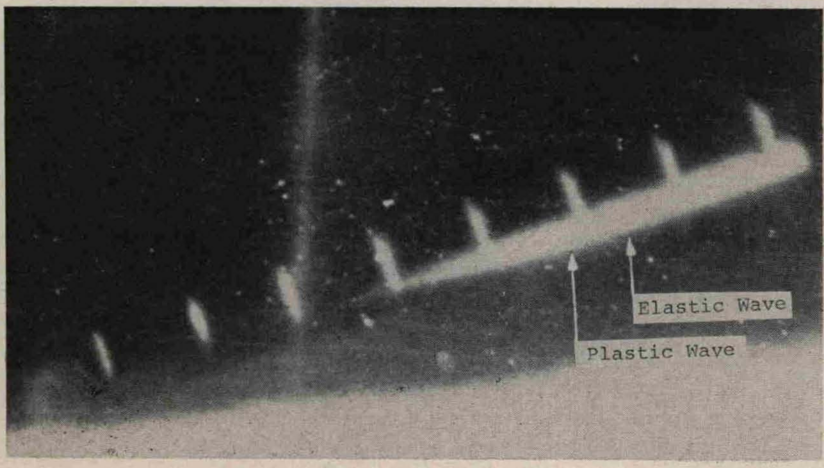

FIG. 2. Sample record of slit area showing intersections of the elastic and plastic waves with the free surface of a granite wedge.