28. HIGH-PRESSURE VELOCITY MEASUREMENTS OF JURASSIC BASALT, LEG 129

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ABSTRACT

Compressional wave velocities and densities were measured for 6 basalt samples from ODP Hole 801B and 16 samples from ODP Hole 801C, a site that represents the first drilling of Jurassic-age crustal rocks in the Pacific basin. Incremental measurements, taken to a total pressure of 200 MPa, show a systematic decrease in velocity with increasing porosity and a related increase in density with increasing wet-bulk density. A comparison of the plot of Jurassic-age crustal rocks in the Pacific basin. Incremental measurements, taken to a total pressure of 200 MPa, show a systematic decrease in velocity with increasing porosity and a related increase in density with increasing wet-bulk density. A comparison of the plot of Jurassic-age crustal rocks in the Pacific basin. Incremental measurements, taken to a total pressure of 200 MPa, show a systematic decrease in velocity with increasing porosity and a related increase in density with increasing wet-bulk density. A comparison of the plot of Jurassic-age crustal rocks in the Pacific basin. Incremental measurements, taken to a total pressure of 200 MPa, show a systematic decrease in velocity with increasing porosity and a related increase in density with increasing wet-bulk density.

INTRODUCTION

One of the goals of Leg 129 was to establish a geophysical reference hole in the oldest Pacific crust to serve as a compliment to the well-established young Pacific crust reference at Hole 504B (1°13.6'N, 83°43.9'W). Site 801 (18°38.5’N, 156°21.6’E) provided an end to this goal with the penetration of 133 m of Jurassic basalt (Fig. 1); preliminary age assignments suggest this is the oldest in-situ ocean floor basalt recovered to date. The volcanic pile sampled at Site 801 consisted of two distinct basalt groups. The lowermost unit has been classified as a tholeiitic basalt (Floyd and Castillo; this volume) and is largely distributed as extrusive pillows and flows. This unit is capped by a thin (10 m) silica and iron hydrothermal deposit which is in turn overlain by highly altered, alkali-olivine basalts occurring as both extrusive pillows and flows and as intrusive sills (Floyd and Castillo, this volume). Figure 2 illustrates the stratigraphic relationships between the igneous units and suggests the likely correlation of material recovered from Holes 801B and 801C.

Age relationships between the units are not entirely clear. It has been suggested that the alkali-olivine basalt postdates the hydrothermal layer and that these basalts may have immediately covered the hydrothermal layer thereby enhancing its preservation (Shipboard Scientific Party, 1990). Floyd et al. (1991) have concluded that further hydrothermal development was probably restricted by the eruption of off-axis alkalic basalts. More recently, K-Ar dating of samples of both basalt groups indicate younger ages for the alkali-olivine basalts than the tholeiites (Pringle, this volume). Indeed, the weathering observed in both groups seems consistent with an interpretation in which the stratigraphic sequence reflects the timing of events; tholeiitic basalts were extruded first followed by deposition of the hydrothermal layer with both later covered by alkali-olivine basalt flows.

We have measured compressional wave velocities, porosities, and bulk densities of samples collected from both basalt groups. Such measurements provide ground truth in the interpretation of oceanic crustal sections by comparison of systematic variations in properties and changes noted in logging runs. In addition, they provide a good approximation of in-situ velocity for the construction of synthetic seismograms and the interpretation of refraction and reflection studies.

EXPERIMENTAL PROCEDURE

We collected a total of 22 samples from Site 801 basalts; 6 samples were taken from Hole 801B and 16 from reentry Hole 801C. All samples from Hole 801B and Samples 801C-1R-3, 96 cm, through 801C-2R-3, 95 cm, are stratigraphically higher than the hydrothermal layer while the remainder of the Hole 801C suite occurs beneath this horizon. Velocity as a function of pressure is tabulated in Table 1. The ends of minicore samples were trimmed and polished at right angles resulting in right cylinders with diameters of approximately 2.5 cm and lengths between 2 and 4 cm. Sample volume was calculated by careful measurement of the minicore diameters and lengths. Water-saturated samples were weighed and bulk densities were calculated from the weights and volumes; porosities were calculated from measured dry and wet densities.

The travel times of compressional waves were measured by the pulse transmission technique using a mercury delay line (Birch, 1964). The velocities are estimated to be accurate to better than 1% (Christensen and Shaw, 1970). All samples were water-saturated prior to the measurements, and pore pressures were maintained at values lower than external pressures by placing a 100-mesh screen between the samples and copper jackets. The screening requires considerable time in the process of sample preparation; however, it is essential that water be allowed to drain from the pore spaces during the application of pressure. All comparative results are given at 60 MPa, an approximation to expected downhole pressures.

DISCUSSION

Figure 3 shows the relationship between compressional wave velocity and porosity for both basalt types. The data are compared with solutions of the equation of Wyllie et al. (1958) which relates measured velocity with porosity as:

\[ \frac{1}{V_m} = \frac{\phi}{V_r} + \frac{1 - \phi}{V_i} \]  

(1)

where \( \phi \) is the fractional porosity, \( V_m \) is the measured velocity, \( V_r \) is the rock velocity, and \( V_i \) is the velocity of the interstitial fluid. The dashed line in Figure 3 shows a solution to the above equation calculated by substituting 1.44 km/s for the interstitial fluid velocity (fresh water) and 6.28 km/s for the rock velocity. A least squares solution for the measured basalt data (solid line, Fig. 3) using the above equation shows reasonable correlation but gives both a lower value for rock velocity and, more importantly, a lower value for the interstitial fluid velocity. The data's...
departure from this ideal relationship suggests strongly that the decrease in velocity is a function of both porosity and composition and therefore demonstrates the general inappropriateness of the Wyllie equation in describing these submarine basalts.

Velocities for the tholeiites, while plotting in the vicinity of the y-axis intercept (6.28 km/s) of the calculated curve, show some scatter. This suggests that the velocity for these rocks may depend more on factors other than porosity. This is further demonstrated by a plot of porosity vs. wet-bulk density (Fig. 4) which shows a clear linear correspondence between density and porosity in the alkali-olivine basalts. Since the porosities of the tholeiites are low, the scatter in tholeiite velocities must be related to composition.

Compressional wave velocity is linearly proportional to wet-bulk density in these basalt samples as well (Fig. 5), with distinct separation of the two basalt types. These results suggest that the density and hence the velocity of these samples is a function of porosity and composition in the alkali-olivine basalts and compositionally related in the tholeiites. The dramatic change in velocity between the two
Figure 2. Stratigraphic relationships between Hole 801B and Hole 801C showing major morphologic units. Depth is given in meters below seafloor (after Shipboard Scientific Party, 1990).
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Figure 5. Compressional wave velocity ($V_p$) at 60 MPa vs. density for alkali-olivine basalts and tholeiitic basalts.

Figure 6. Compressional wave velocity ($V_p$) at 60 MPa vs. depth below the seafloor for alkali-olivine basalts and tholeiitic basalts.