25. COMPRESSIONAL-WAVE VELOCITIES IN BASALTS FROM THE RIO GRANDE RISE[1]

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ABSTRACT

Compressional-wave velocities were measured in 9 samples from the 18 m of igneous basement penetrated by drilling at Hole 516F. Wet-bulk densities range from 2.50 to 2.92 g/cm^3; compressional-wave velocities (measured at 0.4 kbar confining pressure) range from 4.29 to 6.32 km/s. Because of progressive alteration, compressional-wave velocities in deep-sea basalts tend to decrease with age; velocities in basalts from immediately beneath the sediment/basement contact are consistent with the proposed age (86 ± 4 Ma) of basement at the site. A very strong vertical velocity gradient of 0.126 km/s/m in the 18-m basement interval reflects a marked decrease in the degree of alteration with depth beneath the contact.

INTRODUCTION

Our knowledge of oceanic crustal structure and composition is based principally on the interpretation of seismic refraction data. Laboratory studies of the elastic properties of rocks recovered from the deep-sea floor provide a means of correlating lithologies with velocity structures derived from seismic surveys (e.g., Christensen and Salisbury, 1975; Carlson and Wilkens, in press). Further, the primary acoustic horizon in the upper oceanic crust is the contact between basaltic basement and overlying sediments, and the properties of basement rocks at or near the contact have important implications for acoustic-wave propagation. Although the seismic structure of the Rio Grande Rise is not known, we have measured compressional-wave velocities in nine samples from Site 516 to supplement possible future refraction studies and to compare our results with the results of numerous similar studies of oceanic basement rocks from the world oceans (e.g., Christensen and Salisbury, 1972, 1973, 1975; Christensen and Carlson, in preparation[2]).

SAMPLE DESCRIPTIONS

Drilling at Hole 516F penetrated 18 m of basaltic basement, possibly consisting of two or more flow units (Barker et al., 1981). The geochemistry of these rocks apparently reflects the complex origin of the Rio Grande Rise; they have tholeiitic major element affinities similar to Hawaiian tholeiites and Mid-Atlantic Ridge basalts, but are enriched in incompatible trace elements and light rare-earth elements (Thompson et al., this volume).

When fresh, the Hole 516F basement rocks were phyric basalts consisting of plagioclase and clinopyroxene phenocrysts in a fine-grained groundmass. Samples from the top of the interval are extensively altered; alteration decreases with depth (see site chapter, Site 516, this volume). Calcite and iron oxides are common in all of the samples. Vesicles, where present, are commonly filled with clay or calcite. The dominant replacement mineral appears to be calcite, which has replaced much of the matrix and most of the pyroxene in the upper part of the section. Plagioclase phenocrysts are generally fresh in appearence, but there is some evidence of replacement by calcite, particularly in the uppermost samples. Mineral abundances reflect an alteration gradient: calcite content decreases with depth, whereas pyroxene is more strongly in evidence towards the bottom of the hole.

LABORATORY PROCEDURES

Because the degree of water saturation is known to influence the acoustic properties of basalts at moderate confining pressures (e.g., Christensen and Salisbury, 1975), the water-saturated state of the basalt samples was maintained from the time the samples were recovered until the measurements were completed. The samples were cut in the form of right-circular cylinders several centimeters in length, and the densities of the cylinders were estimated by immersion using a Jolly balance. Compressional-wave velocities were measured at confining pressures to 6.0 kbar by the pulse-transmission method (Birch, 1960). Details of the procedure are described elsewhere (Christensen and Salisbury, 1975; Carlson and Christensen, 1977). The estimated accuracy of measured compressional-wave velocities is 0.5% (Christensen and Shaw, 1970).

RESULTS

Wet-bulk density and compressional-wave velocity versus pressure data are summarized in Table 1. Densities range from 2.50 to 2.92 g/cm^3. The corresponding

Table 1. Summary of densities and compressional-wave velocities, Hole 516F.

Core-section (interval in cm)	Wet-bulk density (g/cm^3)	Depth below basement (m)	Velocity (km/s) at varying pressures (kbar)							
			0.2	0.4	0.6	0.8	1.0	2.0	4.0	6.0
126-2, 25–31	2.56	1.8	4.61	4.64	4.66	4.68	4.69	4.73	4.78	4.83
126-2, 38–43	2.56	1.9	4.62	4.64	4.65	4.66	4.67	4.71	4.78	4.84
126-3, 78–88	2.59	2.8	4.50	4.54	4.57	4.60	4.61	4.66	4.75	4.82
126-3, 116–121	2.50	3.2	4.25	4.29	4.32	4.34	4.35	4.40	4.50	4.59
127-2, 60–66	2.56	7.1	4.53	4.56	4.58	4.60	4.61	4.67	4.77	4.85
127-3, 46–52	2.64	7.5	4.94	4.96	4.98	5.00	5.01	5.07	5.14	5.21
127-4, 32–37	2.75	8.8	5.38	5.41	5.43	5.44	5.45	5.48	5.52	5.56
128-1, 90–96	2.86	14.9	6.02	6.05	6.08	6.10	6.11	6.14	6.15	6.16
128-2, 33–39	2.92	15.9	6.30	6.32	6.33	6.34	6.35	6.36	6.39	6.41

[1] Barker, P. F., Carlson, R. L., Johnson, D. A., et al., *Init. Repts. DSDP*, 72: Washington (U.S. Govt. Printing Office).

[2] This "in preparation" reference throughout this paper refers to the manuscript by N. I. Christensen and R. L. Carlson entitled "Seismic properties of igneous and metamorphic rocks recovered by deep-sea drilling."

range of velocities (at 0.4 kbar) is 4.29 to 6.32 km/s. The velocity-density relation for seafloor basalts is illustrated in Figure 1. The dashed line encloses the data field for basalts recovered by the DSDP, Legs 1 through 60 (Christensen and Carlson, in preparation). Dots represent data for samples from Hole 516F. Data from Site 516 fall within the expected range.

DISCUSSION

Christensen and Salisbury (1972, 1973) and Christensen and others (1974) have shown a distinct correlation between compressional-wave velocities in oceanic basalts and bulk density. They point out that the variation in density and corresponding variation in compressional-wave velocity is primarily caused by different weathering stages, and consequently that compressional-wave velocities tend to decrease with age. Figure 2 illustrates the velocity-age relation for samples taken from the uppermost part of igneous basement through DSDP Leg 60 (Christensen and Carlson, in preparation). Although there is considerable scatter in the data, velocities do decrease with age, as suggested by Christensen and Salisbury (1972, 1973). Based on the age of overlying sediments, the age of basement rocks at Site 516 is thought to be about 84 Ma (Barker et al., 1981), and the velocities in the four basalt samples from immediately beneath the contact are in the expected range.

Christensen and others (1974, 1975) have pointed out that the degree of alteration of deep-sea basalts may

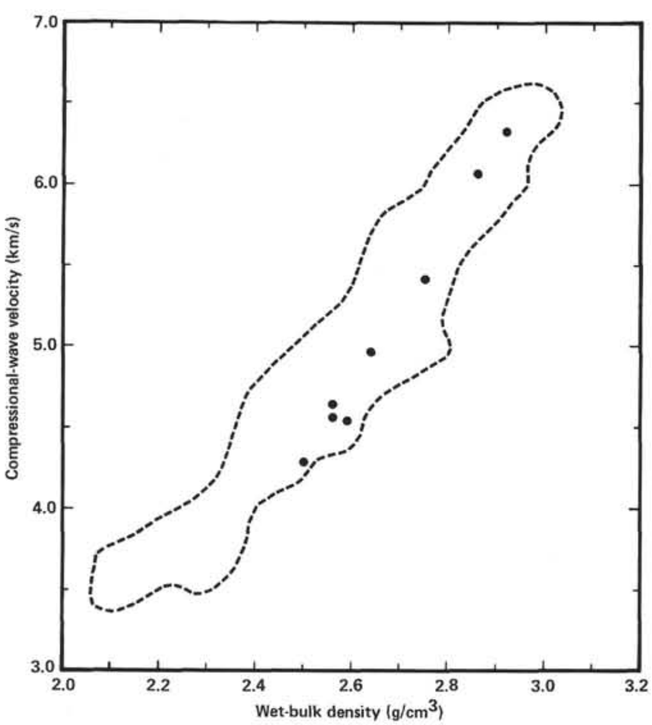

Figure 1. Compressional-wave velocity (measured at 0.4-kbar confining pressure) versus wet-bulk density. The dashed lines show the range of velocity versus density for other deep-sea basalts (Christensen and Carlson, in preparation). Dots represent samples from Hole 516F.

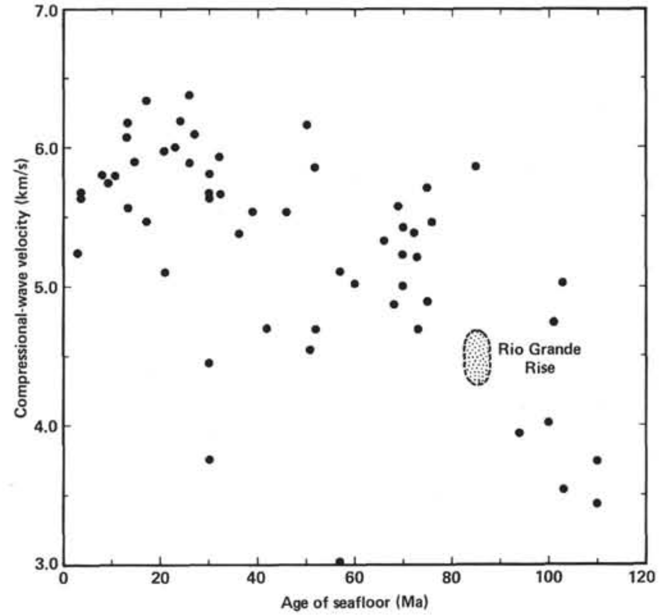

Figure 2. Compressional-wave velocities in samples from uppermost part of igneous basement versus age of igneous basement (adapted from Christensen and Carlson, in preparation). Velocities measured at 0.4-kbar confining pressure. Dotted field includes data for the uppermost four samples from Hole 516F (see Table 1).

also be expected to decrease with depth below the sediment/basement contact, and the marked velocity-depth gradients may result from the alteration gradient. Petrographic evidence indicates that alteration decreases dramatically with increasing depth of recovery at Site 516. The consequent velocity-depth relation is illustrated in Figure 3. The marked inversion near the top of the section may be related to a contact between flow units; calcite also appears to be somewhat less abundant in the samples that have the lowest compressional-wave velocities. The general increase in velocities with depth reflects the progressively decreasing alteration of basalts towards the bottom of the hole.

Velocity-depth gradients for Sites 259 and 261 are approximately 0.04 km/s per m (Christensen et al., 1974), whereas the velocity increases with depth at a rate of about 0.01 km/s per m at Site 292, located on the Benham Rise (Christensen et al., 1975). In marked contrast, the average gradient at Site 516 is estimated by linear regression to be 0.126 ($\pm$0.02) km/s per m. The velocities of rocks only 15 m below the top of basement at this site are comparable with the velocities of unaltered oceanic basalts (e.g., Christensen and Salisbury, 1972, 1973). This result suggests that vertical velocity gradients in the upper parts of the oceanic basement are highly variable and influenced by complex, local conditions that are not well understood.

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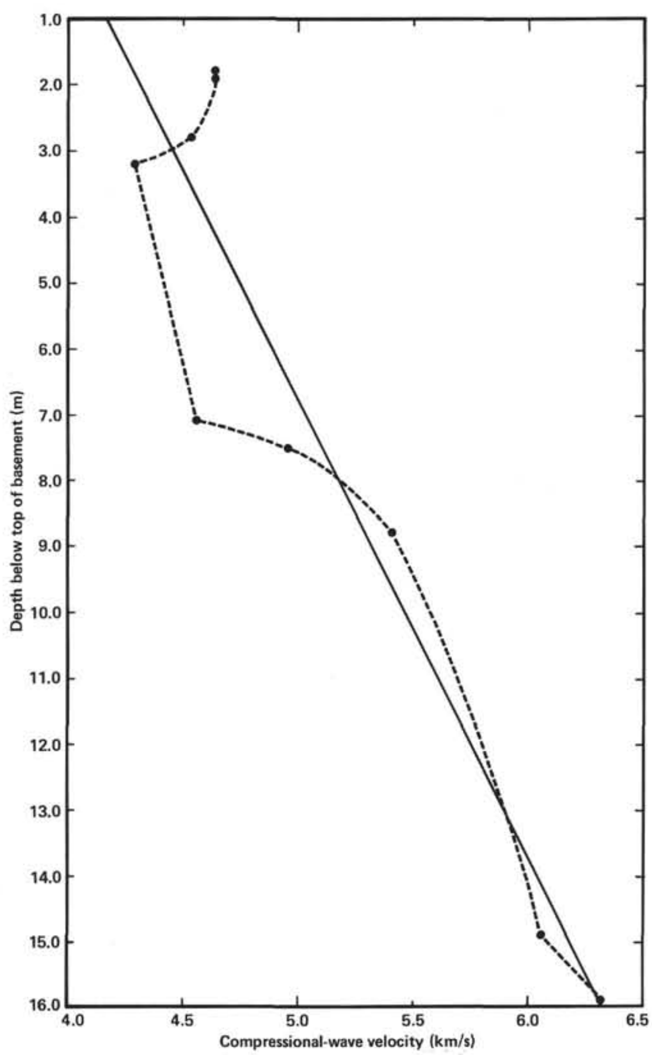

Figure 3. Depth below top of basement versus compressional-wave velocity. The solid line shows the best-fitting linear relation determined by least squares.