15. COMPRESSIONAL WAVE VELOCITIES IN SAMPLES OF BASALT RECOVERED BY DSDP LEG 24[1]

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INTRODUCTION

The velocity of propagation of compressional waves was determined for 16 samples of basalt recovered during Leg 24 of the Deep Sea Drilling Project. Velocity measurements of the samples were first conducted at atmospheric pressure and then at intervals of higher hydrostatic confining pressure up to 7 kb. The velocity data presented here provide useful criteria for correlation of rock types cored at Sites 231, 235, 236, and 238 and Hole 233A with seismic refraction results from the Indian Ocean.

PROCEDURE

Velocity measurements were performed using the modified pulse transmission method (Mattaboni and Schreiber, 1967) as described in Schreiber et al., (1972). Precision of the measurements is 1 percent. Hysteresis, the difference between velocities measured under increasing and decreasing confining pressure, is often observed. The hysteresis is attributed to inelastic changes occurring within a specimen as a consequence of changes in the pore and crack geometry in response to the pressure loading and unloading cycle.

Specimens of 1/2 in. diameter were cut in a direction parallel to the drilling axis; eight of the samples were large enough to allow specimens to also be cut in a direction perpendicular to the drilling axis. Thus, a limited estimate of velocity anisotropism could be obtained. The ends of the specimen were trimmed to produce two flat surfaces that were parallel to within 0.002 cm of each other. Bulk densities of the specimens were calculated from direct measurement of their dimensions and mass. The error in the density determinations is 1 percent. Prior to the velocity measurements, the specimens were jacketed to prevent pressurizing fluid from entering cracks and pores in the rock. Thus, by jacketing the specimens, the effect due to the closing of cracks and pores on the measured velocity could be observed. Specimens were measured in the "as received" condition and were neither dried nor saturated prior to the velocity measurements.

RESULTS

Basalt was recovered at two sites in the Gulf of Aden. Site 231 (Figure 1) was located within the Gulf of Aden, south of the Sheba Ridge, 38 miles north of the Somalia coast. Seismic reflection profiling indicated basement at 565.5 meters below the sediment-water interface, where 17.5 meters of massive basalt was penetrated. Initial petrographic descriptions of these samples (see Chapter 2) indicate that they are slightly altered variolitic basalts containing plagioclase, clinopyroxene, orthopyroxene, finely disseminated opaques, and 40 to 50 percent fresh or palagonitized glass. They appear to be the result of a submarine eruption. The measured velocities of these specimens at 0.5 kb ranged from 4.96 to 5.11 km/sec with an average of 4.87 km/sec (see Table 1 for a summary of the velocity-pressure data).

At Hole 233A, located on the back slope of the Alula-Fartak Trench, 2.6 meters of dolerite were recovered from what was believed to be a sill. These samples are composed of euhedral prismatic plagioclase, subhedral augite, and 20 to 25 percent carbonatized and chloratized glass (see Chapter 4). Velocities at 0.5 kb range from 4.42 to 5.07 km/sec with an average velocity of 4.78 km/sec.

At Site 235, on the eastern edge of the Somali Abyssal Plain, bordering on the west flank of the Chain Ridge, 32.5 meters of porphyritic basalt were penetrated at a depth of 651.5 meters beneath the sediment-water interface. They consist of sericitized and chloritized phenocrysts of plagioclase and olivine in a variolitic groundmass, with interstitial palagonatized, chloritized, or carbonatized glass. Red-brown spinel is a minor constituent, suggesting a deep-seated origin for the parent magma (see Chapter 6). At 0.5 kb, the range of velocities was 5.08 to 5.49 km/sec, averaging 5.39 km/sec. A maximum anisotropy of 0.3 km/sec was observed.

Site 236 is located in oceanic crust northeast of the Seychelle Island block. Some 21.5 meters of greenschist basalt were recovered. Core 33 consists of porphyritic olivine basalt containing phenocrysts of plagioclase, augite, and olivine, which are commonly replaced by serpentine, chlorite, and carbonates enclosed within a microlitic groundmass of plagioclase, augite, and altered glass. One sample from Core 33 had a very low density with a correspondingly low compressional wave velocity. Other samples from Site 236 are predominantly pyroxene basalts with clinopyroxene phenocrysts predominating over plagioclase phenocrysts. These are in a spherulitic and glassy groundmass with analcite commonly replacing plagioclase (see Chapter 7). Compressional wave velocities of these specimens ranged from 4.78 to 5.53 km/sec at 0.5 kb, with an average of 5.00 km/sec. Only two basalts could be cut to yield specimens with different propagation directions and these exhibited a small anisotropy of 0.03 km/sec.

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[1] L.D.G.O. Contribution No. 2108.

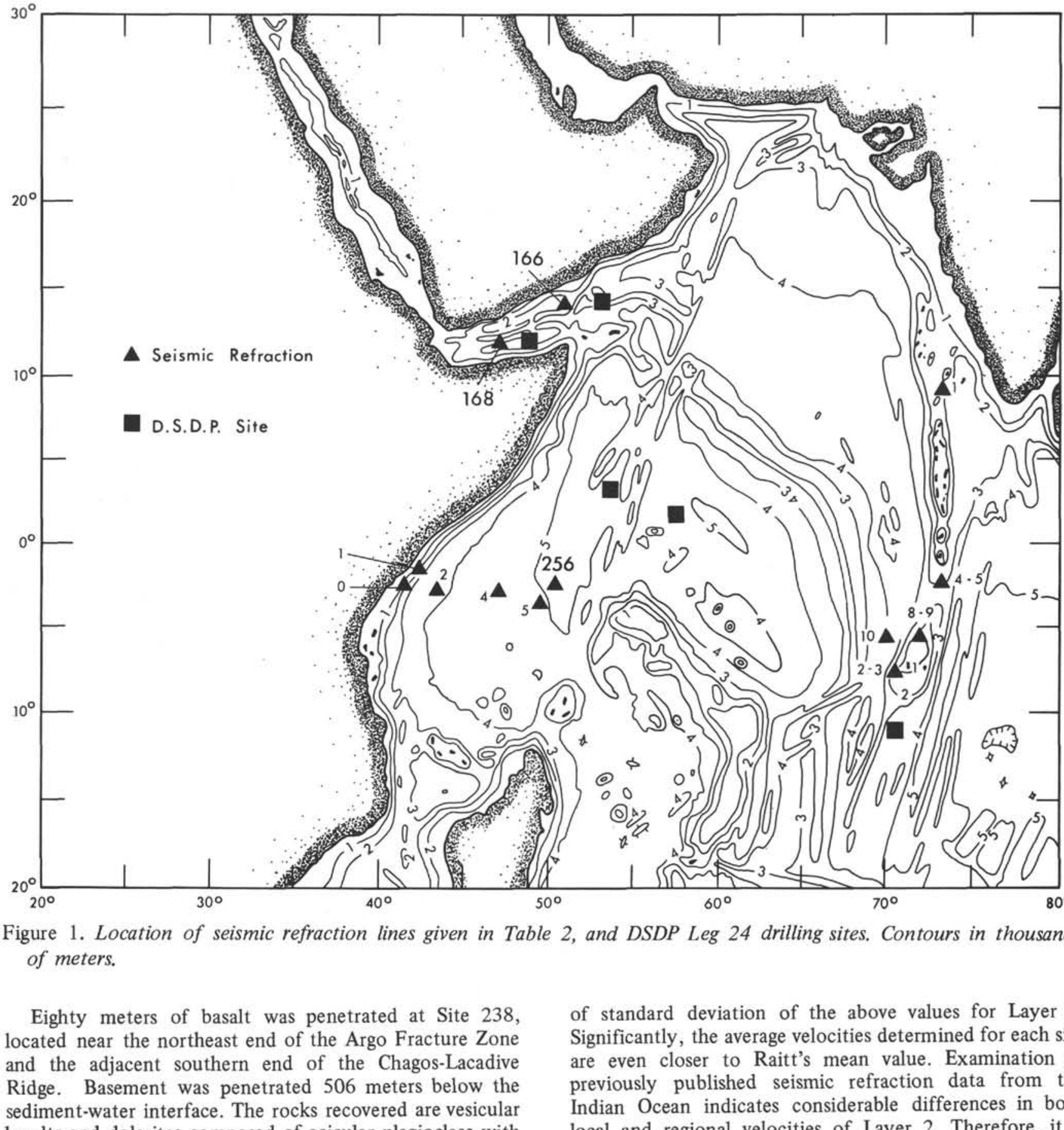

Figure 1. *Location of seismic refraction lines given in Table 2, and DSDP Leg 24 drilling sites. Contours in thousands of meters.*

Eighty meters of basalt was penetrated at Site 238, located near the northeast end of the Argo Fracture Zone and the adjacent southern end of the Chagos-Lacadive Ridge. Basement was penetrated 506 meters below the sediment-water interface. The rocks recovered are vesicular basalts and dolerites composed of acicular plagioclase with intersertal pyroxene and less than 5 percent chloritized glass (see Chapter 9). Measured velocities of 0.5 kb ranged from 5.11 to 5.96 km/sec with an average of 5.51 km/sec.

DISCUSSION

A primary use of the laboratory velocity data is to compare it with seismic refraction results. Raitt (1963) has summarized considerable seismic refraction data obtained in all the major ocean basins and reported a mean velocity of 5.07 ±0.63 km/sec for Layer 2 of the oceanic crust. Except for the sample herein designated as 236-33-3A, all of the measured velocities in this study fall within the range of standard deviation of the above values for Layer 2. Significantly, the average velocities determined for each site are even closer to Raitt's mean value. Examination of previously published seismic refraction data from the Indian Ocean indicates considerable differences in both local and regional velocities of Layer 2. Therefore, it is desirable to correlate our laboratory velocity data with seismic refraction survey lines that are near DSDP sites. However, refraction studies have been done in some of the same physiographic provinces in which these basalts were recovered. A summary of the pertinent refraction work is given in Table 2 and their locations relative to the Leg 24 drilling sites are shown in Figure 1.

Examination of the measured velocities indicates that they are consistent with the range of seismic velocities reported for each physiographic region. A notable exception is Site 231 in the Gulf of Aden, where computed refraction velocities are 0.27 and 0.93 km/sec lower than those found in the laboratory. However, there is good

TABLE 1
Summary of Laboratory Measurements

Sample[a]	Velocity at Pressure, P, (Kb) 0.001	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0	Density (g/cm^3)
231-64-1A	4.87	4.96	5.04	5.10	5.17	5.27	5.33	5.39	5.44	5.49	2.76
231-64-1B	4.30	4.53	4.66	4.75	4.84	4.99	5.09	5.51	5.24	5.30	2.72
231-64-3A	5.00	5.11	5.16	5.20	5.29	5.33	5.39	5.46	5.52	5.56	2.75
233-9-1A	4.25	4.42	4.55	4.66	4.75	4.89	5.01	5.09	5.13	5.16	2.67
233-13-1A	4.65	5.07	5.20	5.29	5.37	5.47	5.56	5.64	5.70	5.75	2.72
233-13-1B	4.52	4.84	5.04	5.19	5.31	5.47	5.57	5.64	5.71	5.79	2.73
235-20-2A	4.67	5.08	5.13	5.19	5.24	5.35	5.45	5.55	5.65	5.75	2.69
235-20-2B	5.08	5.44	5.51	5.55	5.59	5.63	5.68	5.71	5.75	5.79	2.72
235-20-4A	5.00	5.30	5.35	5.39	5.43	5.49	5.56	5.63	5.69	5.75	2.73
235-20-4B	5.20	5.49	5.55	5.58	5.61	5.66	5.70	5.75	5.80	5.85	2.76
235-20-5A	5.28	5.43	5.47	5.51	5.55	5.61	5.66	5.72	5.77	5.82	2.64
235-20-5B	4.89	5.19	5.24	5.28	5.32	5.40	5.49	5.57	5.66	5.75	2.70
236-33-3A	3.16	3.68	3.84	3.97	4.08	4.28	4.45	4.62	4.74	4.82	2.35
236-34-2A	4.75	4.81	4.84	4.86	4.89	4.94	4.99	5.04	5.10	5.15	2.70
236-34-2B	4.53	4.78	4.83	4.86	4.89	4.95	5.02	5.08	5.15	5.22	2.66
236-36-1A	4.92	5.01	5.04	5.07	5.10	5.15	5.21	5.26	5.31	5.37	2.74
236-36-1B	4.70	4.85	4.91	4.95	4.99	5.07	5.15	5.23	5.30	5.37	2.72
236-37-1A	5.34	5.53	5.59	5.61	5.62	5.64	5.65	5.67	5.69	5.69	2.76
238-55-2A	5.21	5.32	5.41	5.47	5.54	5.64	5.72	5.79	5.85	5.91	2.81
238-57-3A	5.42	5.55	5.61	5.65	5.69	5.78	5.84	5.91	5.99	6.07	2.86
238-57-3B	4.95	5.11	5.18	5.24	5.30	5.41	5.49	5.56	5.62	5.65	2.78
238-59-2A	5.71	5.96	6.00	6.02	6.04	6.08	6.12	6.16	6.20	6.24	2.90
238-61-4A	5.41	5.54	5.59	5.63	5.66	5.71	5.76	5.81	5.86	5.91	2.82
238-64-1A	5.30	5.57	5.62	5.66	5.71	5.81	5.89	5.97	6.04	6.11	2.71

[a]A and B denote specimens parallel to and perpendicular to the drilling axis, respectively.

TABLE 2
Seismic Refraction Results for the Northwest Indian Ocean

Refraction Site Number	Location (mean values)	Vp, Layer 2 (Km/sec)	References
166	14°08′N, 50°48′E	4.60	Laughton (1966)
168	11°38′N, 47°02′E	3.94	Laughton (1966)
1	9°05′N, 73°04 E	5.00	Francis and Shor (1966)
2-3	7°50′S, 70°37′E	5.40	Francis and Shor (1966)
4-5	2°10′S, 73°12′E	6.13	Francis and Shor (1966)
8-9	5°30′S, 71°59′E	4.76	Francis and Shor (1966)
10-11	5°40′S, 69°59′E	6.31	Francis and Shor (1966)
0	2°23′S, 41°22′E	4.71	Francis et al. (1966)
1	1°45′S, 42°07′E	4.80	Francis et al. (1966)
2	2°40′S, 43°28′E	5.28	Francis et al. (1966)
4	2°55′S, 47°02′E	5.28	Francis et al. (1966)
5	3°28′S, 49°36′E	4.20	Francis et al. (1966)
256C12	2°39′S, 50°20′E	6.05	Houtz (personal communication)

agreement between velocities averaging 4.78 km/sec from Hole 233A, on the eastern flank of Alula-Fartak Trench in the Gulf of Aden, and seismic profile 166 (Laughton, 1966) that obtained 4.60 km/sec for Layer 2. Slight differences between the measured velocities and seismic velocities in the Gulf of Aden may be due to a number of compositional and/or physical differences in the rocks composing Layer 2 or the inadequacy of seismic refraction profiling to determine small-scale velocity variations.

Specimens from Sites 235 and 236, northeast of the Seychelles Islands, yield velocities that are consistent with the range of seismic velocities recorded for the Somali Basin (Francis et al., 1966). The same result is found by comparing laboratory data from Site 238, south of Chagos Archipelago, with seismic velocities reported for the Chagos-Laccadive Ridge (Francis and Shor, 1966). The great velocity variations in each of these different regions does not justify a more complete comparison with laboratory data, but emphasizes the desirability of selecting drilling sites near seismic survey lines.

Another useful application is to examine this data in terms of a velocity-density relationship. Birch (1961) has shown that for rocks having similar values of mean molecular weight, a linear relationship exists between compressional velocity and density. This relationship is useful in obtaining estimates of density for interpreting gravity data from the seismic velocity data. Figure 2 shows the results for the DSDP Leg 24 samples. The line obtained has a least-squares determined slope of 3.72 km-cm^3/g-sec with a standard deviation of ±0.62. In spite of the complexity of the Indian Ocean, this result suggests that the velocity density relationship may have validity throughout this ocean basin.

Velocity and density measurements of these samples were obtained at atmospheric pressure shortly after recovery aboard the *Glomar Challenger*. In general, both values were higher than reported here. Drilling operations allow the basalts to be at least partially saturated with seawater if they are not already saturated in situ. It is well known (Nur and Simmons, 1969) that the presence of pore water at zero pore pressure results in an increase in measured velocity; the amount of increase is dependent on the amount of pore water. The question still remains as to whether these basalts were saturated in situ or not. Initial results (Schreiber and Perfit, in preparation) indicate that

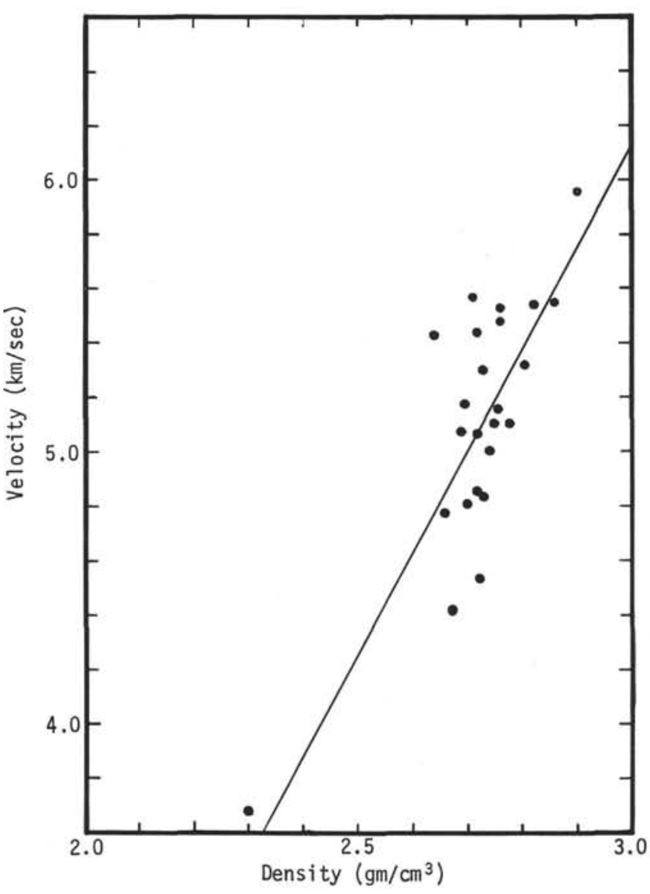

Figure 2. *Plot of density versus compressional velocity at 0.5 kb. The line is a calculated least-squares fit to the data ($V = 3.72\rho - 5.05$).*

the velocities of unjacketed saturated basalts between 0.5 and 1.5 kb is within 2 percent of the jacketed dry velocities. The consistency of our data, together with earliest results for DSDP Legs 14 and 15 (Fox et al., 1972; and Fox and Schreiber, in press) compared with the range of average velocity of Layer 2, leads us to believe that in situ water content is not an important parameter in the determination of velocities in the upper oceanic basement.

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