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VELOCITIES, ELASTIC MODULI AND WEATHERING-AGE RELATIONS FOR PACIFIC LAYER 2 BASALTS

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Compressional (V_p) and shear (V_s) wave velocities have been measured to 10 kb in 32 cores of basalt from 14 Pacific sites of the Deep Sea Drilling Project. Both V_p and V_s show wide ranges (3.70 to 6.38 km/sec for V_p and 1.77 to 3.40 km/sec for V_s at 0.5 kb) which are linearly related to density and sea floor age, confirming earlier findings by Christensen and Salisbury of decreasing velocity with progressive submarine weathering based on studies of basalts from five sites in the Atlantic. Combined Pacific and Atlantic data give rates of decreasing velocity of −1.89 and −1.35 km/sec per 100 my for V_p and V_s respectively. New analyses of oceanic seismic refraction data indicate a decrease in layer 2 velocities with age similar to that observed in the laboratory, suggesting that weathering penetrates to several hundred meters in many regions and is largely responsible for the extreme range and variability of layer 2 refraction velocities.

1. Introduction

Recent laboratory studies by Christensen and Salisbury [1] have shown that compressional and shear wave velocities through basalts recovered from the uppermost few meters of layer 2 at six Atlantic sites of the Deep Sea Drilling Project vary linearly with density and that variations in density, in turn, are related to alteration resulting primarily from submarine weathering. Of particular significance, both density and velocity were found to decrease with age from the ridge crest to the abyssal plain. It was thus suggested that layer 2 velocities obtained from careful refraction surveys might possibly be used to determine submarine weathering rates and approximate ages of the sea floor. It was further suggested, since the range of compressional wave velocities measured in the laboratory was found to be similar to that observed for layer 2 from refraction surveys, that weathering might be responsible for the extreme variability [2] long noted in layer 2 refraction velocities.

These early conclusions were regarded as only tentative due to the limited number of sites studied and the uncertainty in the reported intrusive-extrusive relations at these sites. Due to the importance of these findings in the interpretation of marine refraction results and the theory of sea floor spreading, it was felt necessary to expand this study to include basalts from other ocean basins for comparison with the Atlantic data. In this paper we present seismic velocities, elastic moduli, and densities for cores of basalt from 14 new sites drilled during Legs 5, 6, 7, and 9 in the Pacific Ocean and compare these findings with our earlier results. In addition, we present an analysis of reported layer 2 refraction velocities which indicates that the effects of submarine weathering observed in the laboratory can be clearly discerned in refraction data as well.

2. Experimental procedure and data

Samples were selected for velocity measurements from sites in which sufficient quantities of basalt were recovered to obtain cores 1.28 cm in diameter and 2.5 to 3.5 cm in length. A summary of the sites from which samples were available is given in table 1 and their locations indicated in fig. 1. More detailed descriptions of these sites and the basalts recovered can be found in volumes V, VI, VII, and IX of the Deep Sea Drilling Project [3–6].

Velocities given in table 2 were obtained by the pulse transmission technique [7,8] through samples of know length under conditions of confining pressure and water saturation identical to those described by Christensen and Salisbury [1]. Sample identification numbers refer to the leg, hole, and core numbers and indicate whether the cores were cut parallel (||) or perpendicular (⊥) to the site drill hole. In table 3 the ratio of compressional to shear wave velocity (V_p/V_s), Poisson's ratio (σ), the seismic parameter (ϕ), bulk modulus (K), compressibility (β), shear modulus (μ), Young's modulus (E), and Lamé's constant (λ) are calculated at selected pressures from mean velocities and density for each basalt.

3. Velocity-density relations

As in our previous study of Atlantic basalts [1] we find an excellent correlation of seismic wave velocity with density. Compressional wave velocities at 0.5 kb (an approximate pressure for layer 2) vary from 3.70 km/sec for the lowest density sample (2.09 g/cm^3) to 6.38 km/sec for the highest density basalt (3.00 g/cm^3). Shear velocities range similarly from 1.77 to 3.40 km/sec. The velocity-density relations for the Pacific basalts agree well with our findings for the Atlantic basalts, as are illustrated in figs. 2 and 3. It should be noted that wider ranges of velocities and densities were found for the Pacific basalts because several of the Pacific samples are older than the oldest Atlantic basalts.

Least-square regression line parameters of velocity on density and density on velocity for the Pacific basalts are given in table 4 at selected pressures. These agree well with similar data for Atlantic basalts [1]. It appears that layer 2 basalt velocities can be estimated from bulk densities to better than 0.2 km/sec.

For several sites (5-34-18, 6-54-9, 7-61.1-2 and 7-63.0-11) there are small, but significant variations of velocity with propagation direction. This "apparent anisotropy" is clearly not a consequence of preferred mineral orientation, since the bulk densities of the cores from each of these sites vary systematically with the velocities. Petrographic examination of thin sections cut from the cores used for the velocity measurements show that the variations in density and

TABLE 1
Site summary

Leg	Site	Latitude	Longitude	Water depth (m)	Sediment thickness (m)	Amount of basalt recovered (m)	Age of oldest sediment (my)
5	32	37°07.6'N	127°33.4'W	4758	214	0.5	32 (38*)
5	34	39°28.2'N	127°16.5'W	4322	383	0.9	30 (31*)
5	36	40°59.1'N	130°06.6'W	3273	115	0.3	13 (8*)
6	54.0	15°36.6'N	140°18.1'E	4990	292	1.5	20
6	57.0	08°40.9'N	143°32.0'E	3300	330	3.0	27
7	61.0	12°05.0'N	147°03.7'E	5570	93	2.1	80
7	61.1	12°05.0'N	147°03.7'E	5570	89	0.6	80
7	63.0	00°50.1'N	147°53.4'E	4486	561	3.6	33
7	66.0	02°23.6'N	166°07.3'W	5310	192	0.2	97
9	77B	00°28.9'N	133°13.7'W	4291	470	0.3	36
9	79	02°33.0'N	121°34.0'W	4574	411	0.5	21
9	82	02°35.5'N	106°56.5'W	3707	214	0.3	9
9	83	04°02.8'N	95°44.3'W	3646	241	0.3	11
9	84	05°44.9'N	82°53.3'W	3096	252	0.3	8

* Anomaly age determination.