THE INFLUENCE OF PORE PRESSURE ON OCEANIC CRUSTAL SEISMIC VELOCITIES

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There is strong evidence from marine heat flow investigations and deep ocean drilling that interconnected fractures persist to considerable depths within the oceanic crust. It is well known that many physical properties of the crust including seismic velocities are affected by the abundance of these cavities. Furthermore, the seismic properties of a given depth within the oceanic crust are strongly influenced by fluid pressures within the fractures and pores.

To better understand how pore pressure can influence oceanic crustal seismic structure, velocities have been measured as functions of confining pressure (P_c) and pore pressure (P_p) in the range of 0 to 200 MPa (0 to 2 kbars) for pillow basalt from the Juan de Fuca ridge, dolerite from the sheeted dike section of the Samail ophiolite, Oman, and gabbro from Iceland. The cylindrical rock samples, approximately 2.5 cm in diameter and 5 cm long, were placed in thin shell aluminium cylinders which separated the pore pressure fluid (distilled water) from the confining pressure fluid (hydraulic oil). Pressures were generated by hand pumps and monitored with identical Heise gauges with accuracies of 0.1 percent of full scale. Velocities were measured using the pulse transmission technique and a calibrated variable length mercury delay line (Birch, 1960). Data points were taken (1) at several confining pressures with atmospheric pore pressure; and (2) while holding a constant differential pressure (confining pressure minus pore pressure). The accuracy of a given velocity measurement is 1 percent and the repeatability is 0.5 percent of the measured velocity.

Velocities for the three samples are shown in Figs. 1–3. The solid curves show the velocities at atmospheric pore pressure. Data points beneath the

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solid curves are measured velocities at elevated pore pressures. The dashed lines are lines of constant differential pressure.

Major conclusions resulting from these measurements are as follows:

(1) For regions within the oceanic crust where cracks are open and pore fluid is present, seismic velocities will be highly dependent on pore pressure and any interpretation of velocities in terms of porosity and mineralogy must also take into consideration pore pressure. Crustal regions of overpressure and underpressure will have anomalous velocities which are dependent upon depth, porosity, pore geometry and the deviation of pore pressure from hydrostatic.

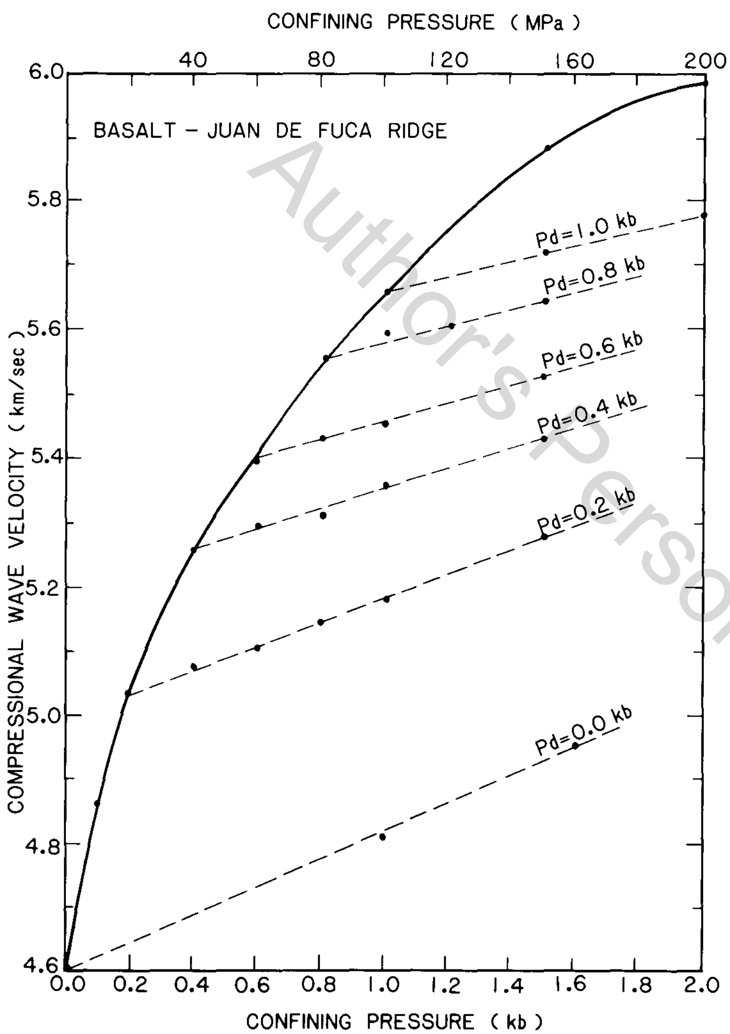

Fig. 1. Basalt velocities as functions of confining pressure and differential pressure (P_d).

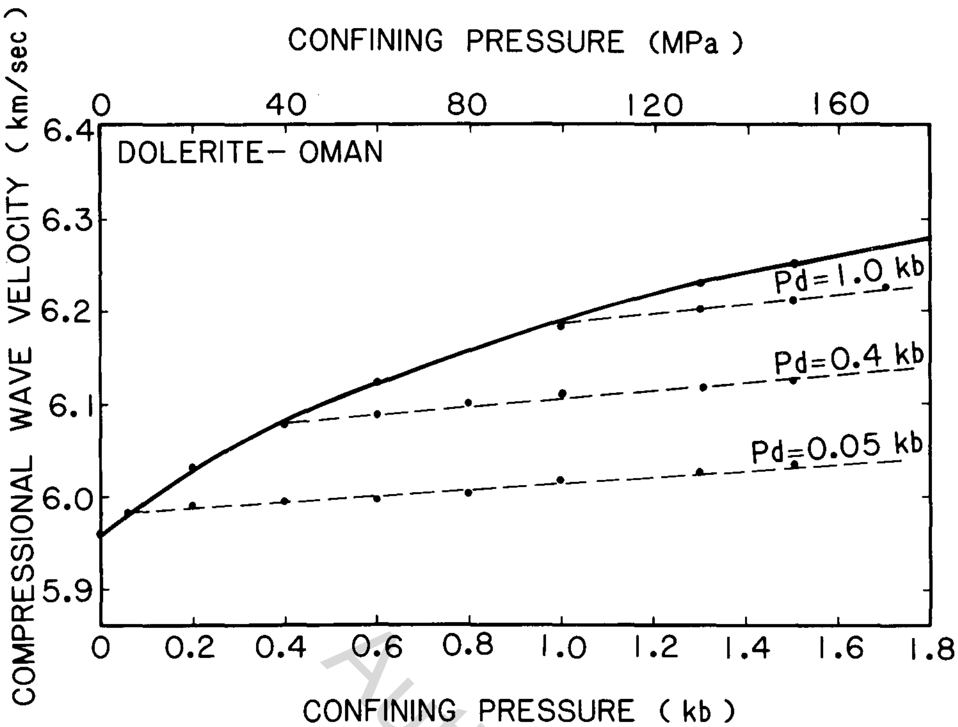

Fig. 2. Dolerite velocities as functions of confining pressure and differential pressure (P_d).

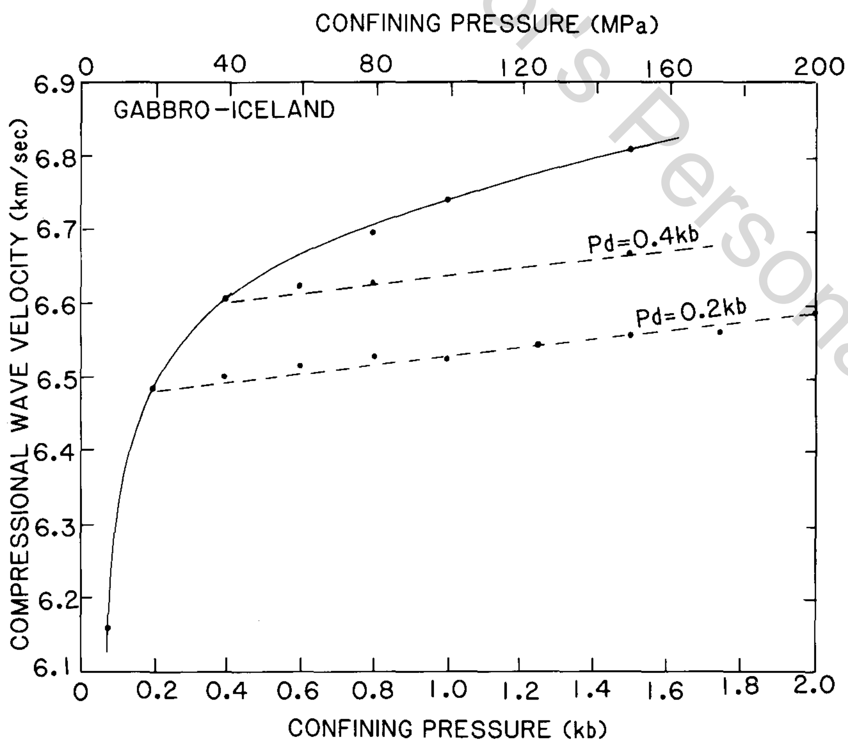

Fig. 3. Gabbro velocities as functions of confining pressure and differential pressure (P_d).

(2) The changes in velocities with increasing pore pressure are much greater for the basalt than the dolerite and gabbro. This is related to the higher porosity of the basalt. In a similar fashion, velocities are expected to be influenced to a greater extent by pore pressure in the upper basaltic regions of the oceanic crust where fractures have been observed to be more abundant (e.g., Young and Cox, 1981).

(3) For all three samples, velocities were found to be dependent on an effective pressure $P_e = P_c - nP_p$, rather than differential pressure $P_d = P_c - P_p$, where $n < 1$. This is illustrated in Figs. 1–3 where velocities do not remain at constant differential pressures, but instead increase with increasing confining pressure at constant differential pressures.

(4) The use of seismic velocities to infer densities of the oceanic crust must be viewed with caution, since pore pressure has little effect on density, but can change velocities significantly.

ACKNOWLEDGMENTS

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