**Final Technical Report for Office of Naval Research**
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Project Title: LABORATORY STUDIES OF PORE PRESSURE, ATTENUATION, ANISOTROPY AND INHOMOGENEITIES IN THE OCEANIC CRUST


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## Objective Research

The purpose of this project was to study the composition, genesis and evolution of oceanic crustal rocks by investigating the relationships between mineralogy, porosity, seismic velocity and seismic attenuation. These properties are dependent on the processes which form the oceanic crust and change as the crust evolves.

## Introduction

The Purdue Rock Physics Laboratory was funded for several years by ONR to investigate the relationships between porosity, seismic velocity, seismic attenuation and mineralogy in rocks from oceanic environments. To better understand the role of porosity on physical properties our measurements have been made at pressures ranging from atmospheric to several hundred MPa. Since the seismic response of a medium is affected by porosity on all scales, this research often required data on porosity, void aspect ratios, and fracture density, as well as information on pore filling material, rock matrix alteration products, and primary mineralogy. The ultimate goal of several projects supported by ONR was to describe the mechanisms by which crustal aging affects physical properties, most importantly porosity and seismic properties, and to investigate how predicted changes might actually be measured. This research included laboratory measurements of physical properties, measurements of porosity, structure, electron microscopy imaging of cracks and pores, and velocity-porosity systematics through numerical modeling using rock physics theory. Although emphasis was placed on high pressure physical property studies of oceanic layer 2 basalts, our research also included studies of sedimentary rocks, such as oceanic chert, and lower oceanic crustal rocks ranging in composition from serpentinite to gabbro.

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## Results

Seventeen publications resulting from this research are listed below. Note that the last paper on basalt glass is in press and will be published in 1998. We also have a manuscript in preparation on the effects of pore pressure on basalt attenuation, which should be ready for submission within the next month.

We received AASERT funding for one graduate student, Joel Johnston, who is co-author on several of the publications. A major part of Johnston's Ph.D. thesis was the 1997 Geophysical Journal International paper "Seismic Properties of Layer 2 Basalts." In this paper the physical properties of oceanic layer 2 basalts were examined with the emphasis on microcrack porosity and alteration-related changes in physical properties. Over 160 core samples from some of the more significant Deep Sea Drilling Project/Ocean Drilling Program holes, including 417D, 418A, 504B and 801C were included in the investigation. The focus of this study has been on two aspects of layer 2 basalts that have received relatively little attention: microcrack porosity and alteration-related changes in physical properties. Alteration, effectively constrained by sample $K_2O$ content, has been shown to result in lowered velocities and increased Poisson's ratios relative to values for fresh basalts.

Porosities and pore aspect ratios of the basalts have been investigated using several complementary techniques. SEM images indicate that natural fractures either healed by late crystallization or sealed by alteration minerals such as smectite and calcite are found throughout the sample suite. Abundant clay- and chlorite-filled microcracks are found in the transition zone and below in Hole 504B. The most significant microcrack porosity trend identified in the basalt suite is attributed to stress relief, which occurred when the original drill cores were removed from *in situ* conditions. Stress-relief microcracking is particularly apparent in the deeper samples from holes 417D and 504B. The relatively severe microcracking observed in coarser-grained basalts is attributed to the large intrinsic 'flaws' in these samples and the fact that decompression-induced stresses become highly concentrated at these features. Thus, fine-grained basalts with micro- or cryptocrystalline ground-masses are apparently not as affected by decompression. This grain-size dependence of stress-relief microcracking has not been recognized previously. Although the results of this study suggest that caution should be exercised in the interpretation of low-pressure laboratory rock-velocity data, stress-relief microcracking in DSDP/ODP basalts may not be as severe as that found in quartz-bearing rocks.

In addition to several papers on crystalline oceanic rocks, we have studied seismic properties of several sedimentary rocks. Seismic anisotropy in sedimentary rocks was investigated by Johnston and Christensen (1994, 1995). The first measurements of velocities in oceanic chert were published by Wilkens, Christensen and Collins, 1993. In this study laboratory measurements and synthetic seismograms were used to illustrate the extreme reflectivity of chert layers when they are present in typical oceanic sediment columns. Cherts are volumetrically abundant in some North Pacific sediment columns and occur in many settings throughout the world oceans. Because they contrast so greatly with more normal pelagic sediment in their seismic properties, they are significant contributors to seismic-reflection records even when their occurrence is relatively insignificant in terms of overall sediment lithology.

In the paper, which is currently in press in Tectonophysics, we report for the first time seismic velocity values for a pure (>95%), natural, submarine basalt glass of Mid-ocean ridge basalt composition, from 10 to 1000 MPa at room temperature. These new data show that basalt glass, abundant in the upper oceanic crust, has the lowest velocity of any primary solid component of the oceanic crust. In addition, natural basalt glass has a steeper pressure-dependence of velocity than previously measured in more crystalline samples, indicating that cracks in natural basalt glass are weaker than in more crystalline rocks. To obtain values for the pure glass phase, we correct the natural glass data for the low-pressure closure of cracks, and the presence of minor mineralogic components and vesicles. These new data provide a baseline for evaluating the effect of abundant basalt glass and glassy mesostasis in oceanic upper crust on *in situ* seismic velocities. In addition, data on the elastic and seismic properties of natural glasses is useful for a better understanding of glass structure, and glass relaxation, with potential applications to submarine volcanology.

The generous support by ONR over the past several years for our investigations of oceanic crust structure and composition is greatly appreciated.

Office of Naval Research Acknowledged Publications over the Past 5 Years

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