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High Resolution Measurements of the Shallow Structure of Oceanic Crust

Final Report

G. M. Purdy and J. A. Collins

Long Range Scientific Objectives

The principal long range objective of this program was to understand the processes that determine the seismic velocity structure of oceanic crust sufficiently well that they may be expressed in a quantitative form and be included in a meaningful predictive model of crustal structure.

Project Description

This program has supported a wide range of marine seismological research: one cruise to the Juan de Fuca Ridge in 1989, a program of technical development culminating in the construction of a new version of the unique deep-towed seismic source NOBEL, the development of new models of the detailed stratigraphy of the oceanic crust and the development with a large portion of the US seismological community of plans for a program of detailed study of the patterns of systematic evolution of the shallowmost velocity structure of the oceanic crust.

The basis for this program was the recognition in the middle 1980's that the original findings of Houtz and Ewing (1976) - that the velocity of the uppermost igneous crust systematically increases as it moves away from the mid-ocean ridge at which it was formed - had profound effects on the nature of low-frequency acoustic bottom interaction. There was a need for new measurements to better define the trends first reported by Houtz and Ewing, and a need for improved understanding of the evolutionary processes that control the changes in porosity structure in the uppermost crust, that in turn determine its seismo-acoustic properties. It was towards these goals that this program was directed.

Primary Accomplishments

Three important accomplishments can be defined:

• The definition of the layering of the shallowmost crust: the importance of the thin surficial low velocity layer to both the structure of the shallow crust and to our understanding of how it is formed was revealed through the careful work of Joint Program student Gail Christeson whose PhD research was supported to a large extent by this project. The boundary at the base of this layer represents a profound change in physical properties and is surmised to constitute the top of the dike sequence. The physical properties of the volcanic seafloor are controlled by the properties of this layer that evolve through time as alteration modifies the geometry of the cracks and pores that constitute its porosity.

• The continued development of the NOBEL instrument system. NOBEL (Near Ocean Bottom Explosives Launcher) was unfortunately lost during the Juan de Fuca cruise in 1989, but has since been improved and rebuilt and now provides a unique capability to carry out high resolution seismic experiments with both source and receiver actually at the ocean floor. NOBEL can detonate on command from the research vessel up 47 10-15 lb explosive charges within a few meters of the ocean floor and can fire one charge every 2-2.5 mins allowing placement of sources at spacings of a few tens of meters.

• Modelling studies have revealed that observations of the characteristics of this uppermost layer can reveal important new insights into the spatial and temporal variability of the crustal accretion process. Mapping of the precise geometry of the base of this layer can reveal the history of faulting, and measurements of the variations in thickness provide estimates of the variations in extrusive volume which in turn may be controlled by the magnitude of the subsidence of the dike sequence, which in turn is determined by the cooling and contraction of the melt lens underlying the mid-ocean ridge. Studies of this surficial layer, which varies in thickness from 100-400m are therefore of fundamental importance to the understanding of the processes that control the generation of the oceanic crust.

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